Impact of Erroneous Meteorological Data on VLBI Processing

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1. Our Goals

Meteorological ('met') data is used in VLBI processing in two distinct ways:
1. The pressure is used to calculate the a priori atmospheric delay along the line of site using the Saastamoinen formula for the zenith delay, and a function which 'maps' the zenith delay to the line-of -sight.
2. More recently, temperature measurements are used to calibrate the thermal deformation of the antennas.

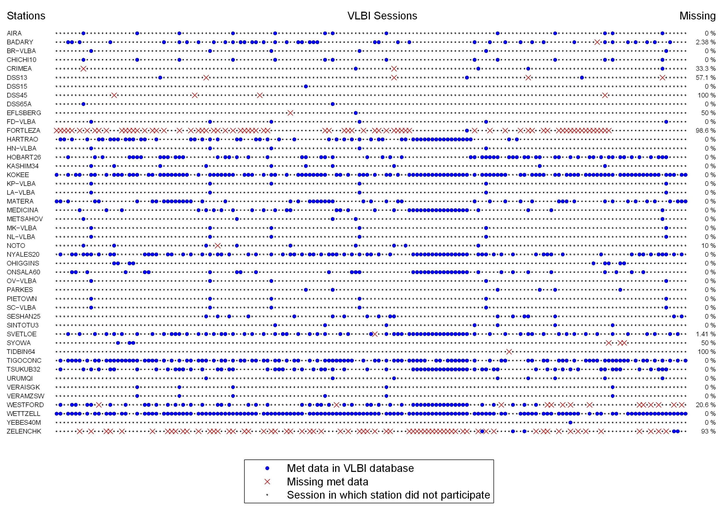
Most VLBI stations have meteorological sensors that record the pressure, temperature and relative humidity. This data is stored in the VLBI 'database', and is used in processing. Sometimes these sensors fail, leading to bad or missing met data. A few VLBI stations have little or no met data.

In the absence of met data, the VLBI analysis package *solve* uses default values for the met data which depend only on the site latitude. These have no seasonal dependence.

In our study we wanted to address the following goals:
1. How often is the met data bad or missing?
2. Are there viable alternatives to using met-data from met-sensors on the site?
3. What is the effect of missing met data on VLBI estimates?

In this poster we present partial answers to all of these questions.

2. Prevalence of the Problem



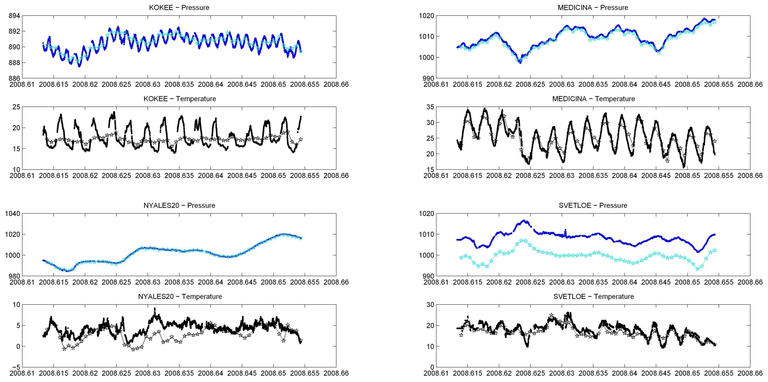
Depending on the site, the amount of missing met data ranges from 0% to 100%. With the exception of Fortaleza (98.6%), Zelenchukskaya (93%), and Westford (20.6%), most frequently observed sites have met-data for almost all of the sessions.

The above figure only indicates that there is met-data in the database. It does not address the issue of whether the data is good or not.

3. CONT08 Comparison of ECMWF With On-Site Met Data

Data from numerical weather forecasting models, such as NCEP or ECMWF, is a possible source to replace bad or missing met-data. An advantage is that the data is always available. A disadvantage is that it is only available on discrete lattice points at 6 hour intervals. To use the data in VLBI processing, you need to interpolate it spatially and temporally. We studied the use of this data during CONT08 and for the year 2008.

We started with publicly available temperature and pressure data at 6 hour intervals derived from ECMWF and spatially interpolated to the location of VLBI sites by the Technical University of Vienna. We used cubic splining to interpolate in time. The figures below compare this data with that from local met-sensors for 4 of the 11 sites that participated in CONT08. Zelenchukskaya had no met data during this period.



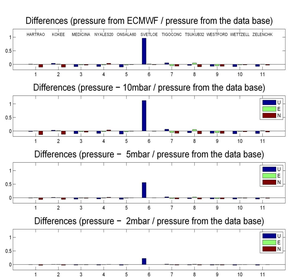
On average the ECMWF met data tracks the data from local site sensors. However, the time resolution of the ECMWF is too coarse to follow short term variations in pressure and temperature, for example, the semi-diurnal variation in pressure seen at Kokee, or the diurnal temperature variations seen at many stations.

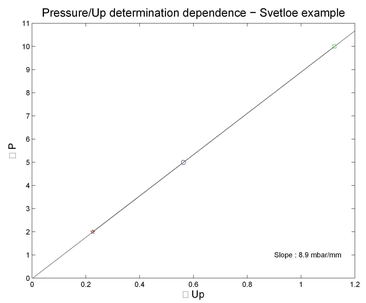
For most sites, with the notable exception of Svetloe, there is no bias between the two pressure series.

4. Using ECMWF Met Data in VLBI Analysis During CONT08

Based on the above, it looks like ECMWF data may be a reasonable source for met data in VLBI analysis. There is, however, the problem of the offset in pressure data at **Svetloe**. An offset in pressure leads to a change in the a priori zenith hydrostatic delay. Naively, this change would all be absorbed into the estimate of the tropospheric delay. We ran a series of solutions to investigate the effect on other parameters:
1. Reference solution with pressure from VLBI database.
2. Solutions using pressure from ECMWF.
3. Solutions where the pressure in the database was offset by 2, 5 and 10 mbar.

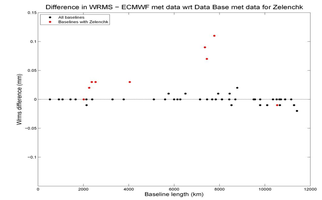
The alternative solutions in 2 and 3 were compared against the reference solution.

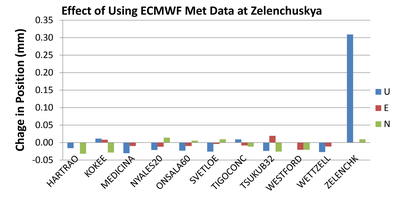




Changing the pressure at Svetloe leads to changes in Svetloe's Up coordinate. The East and North coordinates of Svetloe are barely affected, as are the coordinates of the other stations. The change in Up is a linear function of the change in the pressure, with slope 8.9 mbar/mm.

We mention in passing that the slope is strongly dependent on the minimum elevation. The lower the angle, the larger the effect.

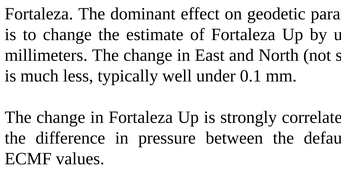


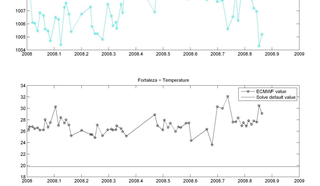


Zelenchukskaya, which had no met-data during CONT08 is a good candidate to see the affect of using ECMF to replace missing met-data. Using ECMWF data improved the day-to-day consistency of the VLBI estimates of station position, as shown by reduction in baseline scatter on 6 of the 8 baselines to Zelenchukskaya. This also had the affect of changing the estimate of local Up at Zelenchukskya by 0.3 mm. The affect on the other coordinates of Zelenchukskaya, and the coordinates of other stations was negligible.

5. Using ECMWF Met Data in VLBI Analysis During 2008

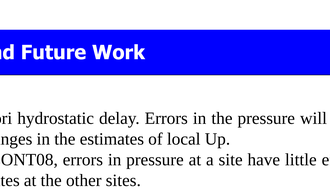
Fortaleza has no met data for 98.6% of the 2008 VLBI sessions. As mentioned previously, in cases where there is no met data, *solve* uses a default constant value. We did a solution with the R1 and R4 sessions using ECMF derived met-data for Fortaleza, and compared it with a solution using default values.





Compared to using default met-data, using ECMWF met-data reduces baseline scatter on baselines to Fortaleza. The dominant effect on geodetic parameters is to change the estimate of Fortaleza Up by up to 2 millimeters. The change in East and North (not shown) is much less, typically well under 0.1 mm.

The change in Fortaleza Up is strongly correlated with the difference in pressure between the default and ECMF values.



6. Conclusions and Future Work

Conclusions:
- The pressure at a VLBI site is used to calculate the a priori hydrostatic delay. Errors in the pressure will lead to errors in the hydrostatic delay, which in turn leads to changes in the estimates of local Up.
- For schedules with good sky coverage, such as those in CONT08, errors in pressure at a site have little effect on horizontal coordinates of the site, or any of the coordinates at the other sites.
- Use of ECMWF reduces baseline scatter, indicating it is a viable alternative to local site-sensors. However, you need to take care not to introduce biases in the pressure data.
- Using a default value for the pressure can lead to errors in local Up of up to 2 mm.

Future Work:
This note looked at the case when the met-data was missing. Another problem is when the met-data is bad, for example, due to a faulty sensor. We plan on comparing met data in the VLBI database with ECMWF data to search for instances of bad data.

7. Acknowledgements

We wish to thank the VLBI group at the Technical University of Vienna, in particular, Johannes Böhm and Harald Schuh, for making their time series of met-data available to us.

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